EXHIBIT C

input part 34 is converted into a feature parameter for speaker verification and sent out to the verification distance calculating part 36A and the speaker distance calculating part 36B.   The verification distance calculating part 36A calculates the distance d_{id} between the voice

5   template of the speaker corresponding to the identity claim and the feature parameter of the input voice.

On the other hand, the speaker distance calculating part 36B calculates the distances d_1, d_2, ... and d_N between the voice templates of N other registered speakers and the feature parameter of the input voice

10   and delivers the results to the distribution estimating part 37.   The distribution estimating part 37 estimates a probability distribution function F(d) of the speaker distances between the voices of the registered speakers other than the speaker corresponding to the input identity claim and the input voice, using the calculated N distances d_1, d_2, ... and d_N with

15   respect to the other registered speakers and delivers the result to the speaker judging part 39.

The estimation of the probability distribution function F(d) leads to a probability density function f(d).   The area of the function shown in the probability density function f(d) indicates a probability value.   The

20   relationship between the probability distribution function F(d) and the probability density function f(d) is that as shown in Equation 1.
Equation 1

$$F(x) = \int_{-\infty}^{x} f(t)\, dt$$

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Therefore, the speaker judging part 39 judges the speaker based on the probability density function f(d) in the following manner.   When the speaker distance d_{id} with respect to the speaker corresponding to the identity claim is within the region defined by the level of significance p of

30   regarding an unauthorized person as the person specified by the ID, which is previously designated in the false acceptance error rate input

part 38, it is determined that the speaker is the person specified by the ID. When the distance d_{id} is not within the region, it is determined that the speaker is not the person specified by the ID. In the determination based on the probability distribution function $F(d)$, when $F(d_{id}) < p$ is

5   satisfied, the speaker is the person specified by the ID. When $F(d_{id}) \geq p$ is satisfied, the speaker is not the person specified by the ID.

Fig. 4 shows a diagram illustrating the method for judging the speaker by the speaker judging part 39. In the case where the probability density function $f(d)$ is already obtained, the hatched region in

10   the Fig. 4 corresponds to the region defined by the level of significance p of regarding an unauthorized person as the person specified by the ID. More specifically, the level of significance p of regarding an unauthorized person as the person specified by the ID is specified to determine that the speaker is the person specified by the ID when the distance d_{id} is in the

15   range in which the level of significance of regarding an unauthorized person as the person specified by the ID is smaller than the designated level of significance p.

Next, Fig. 5 is a block diagram of a speaker verification apparatus of one example of the present invention when verifying the speaker.

20   Referring to Fig. 5, numerals 51A and 51B denote DP matching parts. Numeral 52 denotes a statistic calculating part. Numeral 53 denotes a speaker judging part. Numeral 54 denotes a false acceptance error rate input part.

In Fig. 5, similarly to Fig. 3, an identity claim is input to the ID

25   input part 31 at the time of using a system. Then, the speaker template selecting part 32 selects a template corresponding to the identity claim from templates of a plurality of speakers that are previously registered in the speaker template storing part 33 and sends the selected template to the DP matching part 51A. At the same time, the templates of the

30   registered speakers other than the speaker corresponding to the identity claim are sent out to the DP matching part 51B. Herein, "DP" stands for dynamic programming.

Next, in the voice analyzing part 35, a voice input to the voice input part 34 is converted into a feature parameter for speaker verification and sent out to the DP matching calculating parts 51A and 51B.   The DP matching part 51A calculates the distance d_{id} between the

5   voice template of the speaker corresponding to the identity claim and the feature parameter of the input voice.

On the other hand, the DP matching part 51B calculates the distances d_1, d_2, ...and d_N between the voice templates of N other registered speakers and the feature parameter of the input voice, and

10   delivers the results to the statistic calculating part 52.   The statistic calculating part 52 estimates the average μ and the standard deviation σ of the speaker distances, using the calculated N distances d_1, d_2, ...and d_N with respect to the other registered speakers, and delivers the estimations to the speaker judging part 53.   The speaker judging part 53

15   defines a normal distribution using the average μ and the standard deviation σ of the distances with respect to the other registered speakers.

If the probability distribution is a normal distribution, a probability distribution function F(d) in a point α・σ away from the

20   average μ can be determined by α.   Therefore, whether or not the speaker is the person specified by the ID can be determined by examining whether or not the verification distance d_{id} is in a region where d_{id} is equal to or smaller than (μ − α・σ) in order to determine whether or not the verification distance d_{id} with resect to the input voice is within the region

25   defined by the previously designated level of significance p of regarding an unauthorized person as the person specified by the ID.   More specifically, (μ − α・σ) and d_{id} are compared and the determination is performed as follows.   When d_{id} is equal to or smaller than (μ − α・σ), it is determined that the speaker is the person specified by the ID.   When

30   d_{id} is larger than (μ − α・σ), it is determined that the speaker is not the person specified by the ID.   In the case where it is assumed that the probability distribution is a normal distribution, the false acceptance

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error rate input part 54 inputs α corresponding to the level of significance p of regarding an unauthorized person as the person specified by the ID beforehand.

5 In this embodiment, the feature parameters are registered in the form of templates beforehand, and the probability distribution with respect to other registered speakers is estimated based on the speaker distances obtained by DP matching.   The present invention is not limited to this method.   For example, the probability distribution can be estimated based on a probability value output from a probability model

10 such as Hidden Markov Model.

Furthermore, in the speaker template storing part 33, speakers may be classified by the gender beforehand.   When the speaker corresponding to the identity claim is male, the speaker templates of other male speakers are used for estimation of the probability

15 distribution.   When the speaker corresponding to the identity claim is female, the speaker templates of other female speakers are used for estimation of the probability distribution.   Thus, the error rate of the probability distribution becomes closer to the error rate obtained from the normal distribution function table.   (The identity claim is something

20 which indicates a specific individual such as a name).

Furthermore, in this embodiment, the probability distribution of the speaker distances is estimated as a single normal distribution. However, the probability distribution can be estimated as a mixed normal distribution defined by weighting addition of a plurality of normal

25 distributions or other general probability distributions.   (This is not necessarily limited to the distribution of other registered speakers, and other speakers can be prepared for the calculation of the distribution.)

Next, the effects of this embodiment are confirmed by the results of the following experiments.   First, Fig. 6 is a graph showing the results

30 of verification of 15 male speakers using the speaker verification method of this embodiment.

In Fig. 6, the horizontal axis indicates α obtained from the

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WHAT IS CLAIMED IS:

1.   A speaker verification apparatus comprising:

an identity claim input part to which an identity claim is input;

5   a speaker selecting part for selecting voice information of a registered speaker corresponding to the identity claim input to the identity claim input part;

a speaker storing part for storing voice information of speakers;

a voice input part to which a voice is input;

10   a voice analyzing part for analyzing the voice input to the voice input part;

a speaker distance calculating part for calculating a verification distance between a feature parameter of the input voice and that of the voice of the registered speaker and the speaker distances between a

15   feature parameter of the input voice and those of the voices of speakers other than the registered speaker that are stored in the speaker sorting part, based on the analysis results of the voice analyzing part and the voice information stored in the speaker storing part; and

a speaker judging part for determining whether or not the input

20   voice matches the registered speaker corresponding to the input identity claim,

the speaker verification apparatus further comprising:

a false acceptance error rate input part to which a false acceptance error rate is input as a threshold, the false acceptance error

25   rate being predetermined by a system manager or a user or adjustable depending on performance; and

a distribution estimating part for obtaining a probability distribution of interspeaker distances based on the speaker distances calculated in the speaker distance calculating part;

30   wherein the speaker judging part determines that the input voice is the voice of the registered person specified by the identity claim, in the case where the verification distance calculated in the speaker distance

calculating part is included in a region defined by the input false acceptance error rate in the probability distribution of the interspeaker distances.

5   2.   The speaker verification apparatus according to claim 1,

wherein it is assumed that the probability distribution of the speaker distances is a normal distribution function, and

the speaker judging part determines that the input voice is the voice of the registered person specified by the identity claim, in the case

10 where the verification distance calculated in the speaker distance calculating part is included in a region defined by the input false acceptance error rate in the probability distribution of the speaker distances obtained from the normal distribution function.

15 3.   The speaker verification apparatus according to claim 1,

wherein the probability distribution of the speaker distances is obtained for each gender.

4.   The speaker verification apparatus according to claim 1,

20   wherein the probability distribution of the speaker distances is obtained as a weighting addition of a plurality of normal distributions.

5.   A method for verifying a speaker comprising:

inputting an identity claim;

25   selecting voice information of a registered speaker corresponding to the input identity claim;

inputting a voice of the speaker;

analyzing the input voice;

calculating a verification distance between a feature parameter of

30 the input voice and that of the voice of the registered speaker and the speaker distances between a feature parameter of the input voice and those of voices of speakers other than the registered speaker, based on

the analysis results and the voice; and

determining whether or not the input voice matches the registered speaker corresponding to the input identity claim,

the method further comprising:

5   inputting a false acceptance error rate as a threshold, the false acceptance error being predetermined by a system manager or a user or adjustable depending on performance; and

obtaining a probability distribution of the interspeaker distances based on the calculated speaker distances;

10   wherein it is determined that the input voice is the voice of the registered person specified by the identity claim, in the case where the calculated verification distance is included in a region defined by the input false acceptance error rate in the probability distribution of the interspeaker distances.

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6. A computer-readable recording medium storing a program to be executed by a computer, the program comprising:

inputting an identity claim;

selecting voice information of a registered speaker corresponding

20   to the input identity claim;

inputting a voice of the speaker;

analyzing the input voice;

calculating a verification distance between a feature parameter of the input voice and that of the voice of the registered speaker and the

25   speaker distances between a feature parameter of the input voice and those of voices of speakers other than the registered speaker, based on the analysis results and the voice; and

determining whether or not the input voice matches the registered speaker corresponding to the input identity claim,

30   the program further comprising:

inputting a false acceptance error rate as a threshold, the false acceptance error rate being predetermined by a system manager or a

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user or adjustable depending on performance; and

    obtaining a probability distribution of the interspeaker distances based on the calculated speaker distances;

    wherein it is determined that the input voice is the voice of the
5 registered person specified by the identity claim, in the case where the calculated verification distance is included in a region defined by the input false acceptance error rate in the probability distribution of the interspeaker distances.